Effect of Nano Silicon Nitride, Nano Clay and Sisal Fiber on the Strength and Durability of concrete.

A Synopsis

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SUBBURAJ V

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(DEEMED TO BE UNIVERSITY)

ANAND NAGAR, KRISHNANKOIL – 626 126

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1.0. INTRODUCTION

Cement concrete has been widely used in highway, tunnel, airport road, and city road construction because of its many advantages such as high strength, strong bearing capacity, low cost, high-temperature resistance, and other advantages Silicon nitride (Si_3N_4) is a ceramic material known for its high strength, hardness, and resistance to wear and corrosion. Su, F.H et. Al (2006) has explored the potential use of Nano-Si_3N_4 (NSN) as an additive in cement to enhance its properties. Nano Clay improves the various properties of cement composite as found by Mehrabi et. al (2021) and Niaki MH (2018). Sisal fiber used in cement composite improves the mechanical property of the composite as found by Balaji A et. al. (2019). Natural Sisal Fiber (SF) and Nano Clay were used to enhance the NSN concrete.

2.0. LITERATURE REVIEW

Nano-Si3N4 (NSN) has been studied intensively and have excellent properties, such as superior mechanical properties, high hardness, and strong wear resistance as found by Liu (2021), which have been widely applied in the fields of chemical industry, aviation, pharmaceuticals, automobiles, and other fields, especially as a special ceramic material. Zhang (2017) and Wang (2014) obtained ceramic tool materials with good cutting wear properties by adding NSN. Huang, L. (2019) found that NSN whiskers act as a kind of reinforcing phase, disperse and distribute in the cement matrix, which play a very good connecting role and achieve the effect of strengthening and toughening. Sun et al. pointed out that NSN can improve the bending strength and wear resistance of ceramics with adding NSN. The crystallization behaviour and crystal structure of the polymer could be affected by the addition of NSN particles, thus affecting the properties of the composites. However, there are few reports on the research and application of NSN particles in the field of cement and concrete materials. On the one hand, the application of NSN in functional ceramic materials has been widely studied because of its excellent performance. On the other hand, researchers have paid increasing attention to nanoparticles as a substitute component to improve the performance of cement-based materials. As the key performance index of concrete pavement, it is of great significance to study the mechanical properties of concrete pavement. There is less work on investigating the effect of different amounts of NSN on the physical strength of cementitious materials and durability.

2.1. IMPORTANCE OF THE STUDY

Enhancing the longevity of concrete necessitates the use of concrete that possesses superior durability and strength. Various studies have shown that the addition of nano materials can improve the strength of the concrete. The tests in these studies were done by varying the nano material quantity with respect to the cement content, as a replacement to cement in most cases and as an addition to cement in some cases. Work. The optimal proportion of nano material is governed by several elements such as curing, water to binder ratio, size of nanoparticle, admixture, etc. There is very less work showing the effect of NSN addition to cement. So the properties of the concrete made by NSN need to be addressed. This dictates a requirement of various tests like strength and durability to be done for the NSN concrete made under the control conditions fixed in this study.

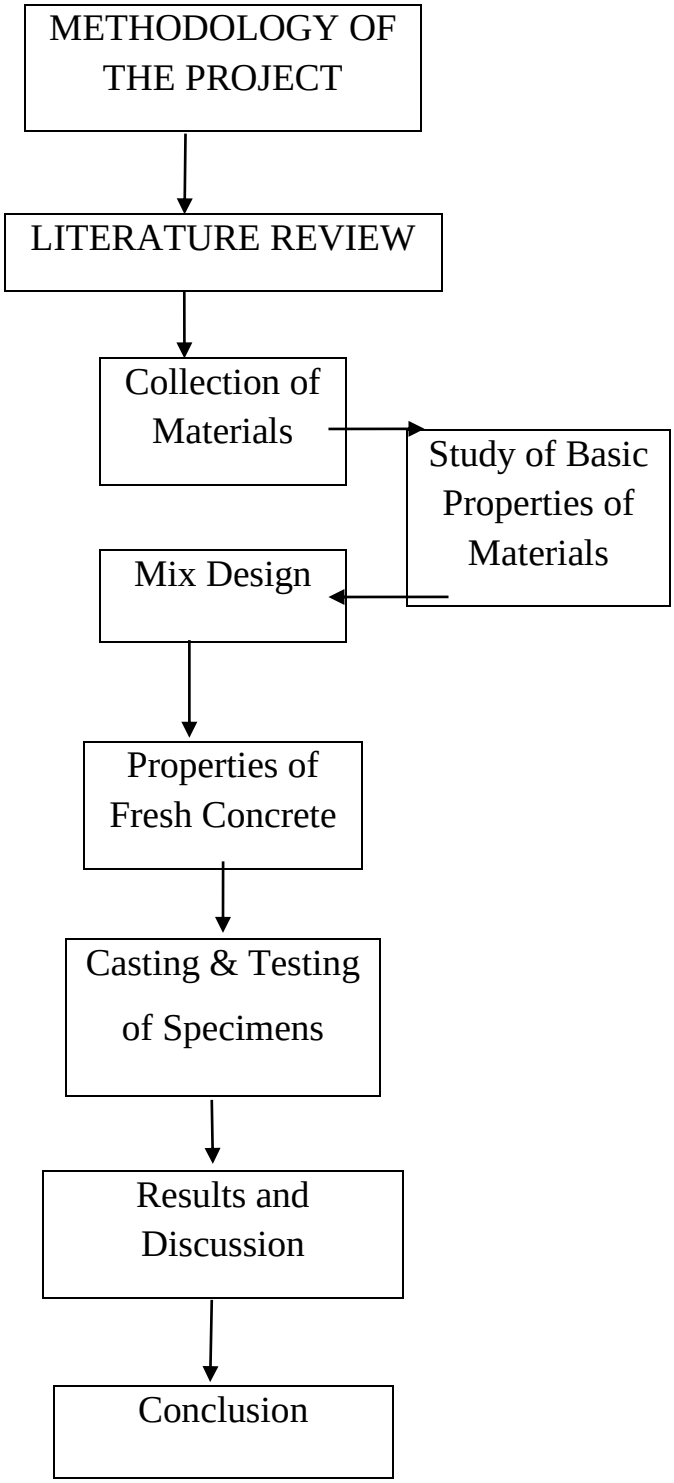
3.0. OBJECTIVES OF THE RESEARCH:

This research work is principally concerned with the strength and durability properties of the cement mortar and concrete containing NSN.

Scope of the research is limited to the following in concrete with NSN:

- To study the water demand of cement paste.
- To examine the change in microstructure properties of cement mortar made with NSN
- To evaluate the density of concrete using Ultrasonic Pulse Velocity (UPV) test.
- To investigate the strength properties at the age of 7 days, 28 days and 90 days
- To investigate the durability properties at the age of 28 days and 90 days.
- To Study the effect of Sisal Fiber and Nano Clay in NSN concrete.

3.2. RESEARCH METHODOLOGY,



3.3 MATERIALS AND METHODS

3.3.1 Materials Used

Ordinary Portland Cement of grade 53 was used in this work. The specific gravity of the FA was found to be 2.6. Sieve analysis was conducted on FA and was found to confirm with Zone III as per IS 383 : 1970. Broken stones were used as coarse aggregate (CA). The specific gravity of the CA was found as 2.73. Sieve analysis was conducted on CA and they were found to be of nominal size 20 mm as per IS 383: 1970. The reduction in workability due to the addition of NSN was compensated by using admixture polycarboxylate superplasticizer. Silane surface modifier 3-Aminopropyltrimethoxysilane was used to improve the water resistant property of NSN.

Thermo-chemical method was used in the process of preparing Si_3N_4 from RHA biomass. The SiO_2 structure was decomposed to rich silicon Si_3N_4 by heating and then grounded to an average particle size was about 500 nm.

Sisal Fiber (SF) and Cloisite 30B nanoclay were utilized as reinforcements. The sisal fiber and nanoclay were provided by Metro Composites.

3.3.2 Mix Proportions and Designations

The preparation of biocement for this study uses 5% (CSA1), 10% (CSA2), 15% (CSA3), 20% (CSA4), 25% (CSA5) and 30% (CSA6) of NSN were added to the weight of cement. Cement mortar was prepared as per ASTM standards. Polycarboxylate superplasticizer of 0.25% was mixed with cement mortar to improve the workability. The mix proportion of 1 : 1.61 : 3.02 with water cement ratio 0.5 was used for cement concrete. The designed mix proportion was taken as the control mix CS. The water-cement ratio was similar for all the mix proportions. All the specimens were water-cured. Addition of SF and Nano Clay was done to CAS2 and CSA3.

3.3.3 Mechanical Properties and Microstructural Properties

Compression test was done for all proportions after 7, 28 and 60 days of curing. Splitting tensile strength test and flexural strength test were done for all the proportions after 28 days of curing. The UPV test was performed on cubes to assess the uniformity of concrete. Scanning Electron Microscope (SEM) was used to examine the microstructure of the cement mortar specimens.

3.3.4 Durability Properties

The RCPT test was conducted in accordance with ASTM C1202. Quantity of current consumed was measured at an interval of 30 minutes for 6 hours.

Sorptivity test was conducted as per ASTM C 1585. The weight of specimens were measured continuously at 60 seconds, 5 minutes, 10 minutes, 20 minutes, 30 minutes, 60 minutes, then for every hour upto 6 h, and then once a day up to 8th day.

4.0.RESULTS AND DISCUSSION

4.1. Consistency Test

The consistency test showed an increase in water demand with increase in NS content. The test was carried out on six different sample proportions from cement with 0% NSN to cement added with 2.5% NS. The percentage increase in water demand for 5% (CSA1), 10% (CSA2), 15% (CSA3), 20% (CSA4), 25% (CSA5) and 30% (CSA6) was 4.3%, 4.9%, 5.5%, 5.9%, 6.7% and 8.8% respectively. When treated with silane the water absorption reduced.

4.2 Slump Test

The slump value of control concrete CS was 98 mm. So to achieve a similar slump in NSN added concrete, superplasticizer required was found by trial and error method.

4.3 Compressive Strength

When comparing the compressive strength results it was observed that the samples containing NSN were having better strength than the control sample. There was an improvement of 17.45 and 34.05% in as-received and silane-treated CAS2 and CSA3 cement mortar cubes respectively. This improvement is the reasons of two phenomenon. The addition of NSN fills in the micropores of the cement mortar and reduced the porosity. This improved the compactness and compressive strength of cement mortar by reducing the free volume. The addition of NSN improved the hydration thus high pozzolanic activity is achieved. Addition of SF and Nano Clay was done to CAS2 and CSA3.

4.4 Flexural Strength Test

The flexural strength of concrete increased by 14.53% when 10% NSN was added. There was 25% increase in flexural strength with the addition of 15% NS (C3). There was a reduction in strength from 20% NSN addition.

4.5 Splitting Tensile Strength Test

The split tensile strength increased by 4.89% when 10% of NSN was added. This test showed a steady increase in strength with increase in NS content upto 15% NS (C3). Whereas an addition of 20% NS (C4) reduced the strength.

4.6 Ultrasonic Pulse Velocity Test

The samples with NSN have a faster pulse velocity than the sample without NSN. This must be due to the presence of excess NSN particles that support the easy transmission of pulse through the concrete.

4.7 Microstructure

The SEM image of plain OPC shows the coarse grains of cement molecules, which confirms the less nucleation effect. Since no reinforcement the binding of sand particle take large space and formed large grain structure. In CSA3 the grains are smaller and available with the particle of NSN. It was noted that in as-received CSA3 some agglomeration of NSN was evidenced. This was possibly due to the interfacial attractions between particle and the reaction between the water molecules whereas in silane-treated CSA3 the particles are well dispersed in the matrix without any giant agglomerations. The Si and N elements are dispersed uniformly throughout in the OPC matrix indicating the effective dispersion of fillers. Effective silane coverage on the particle is the reason for this improvement.

4.8 Sorptivity

The specimen with no silica had a higher initial rate of absorption as well as secondary rate of absorption. The rate of absorptions decreased with the addition of in the Nano Silica and Micro Silica. This shows the presence of Silica increases the density of the concrete and improves pore structure. Park *et al. (2012)* have found that permeability is

influenced by the surface water absorption of concrete. This proves that reduced surface water absorption improves the durability of concrete.

4.9 Rapid Chloride Penetration Test

There was reduction in charge passed with increase in silica content. Also the current reading at 30 minute interval increased up to 6 hours in a linear fashion for all samples. The chloride permeability of the concrete reduced due to the increased density of the concrete and blocking of pores as found by Ye, H, et. Al (2017). The comparison of the water absorption (in sorptivity test) and current flow (in RCPT) with respect to time (6 hours). The slope followed by both water absorption and current flow are similar.

5.0. ORGANIZATION OF THESIS

The Thesis is constituted into five chapters as given below

Chapter 1 Introduction

This chapter gives a general introduction to durability and materials used and it highlights the need for this study and also provide the objective of this research work.

Chapter 2 Literature Review

This chapter throws light on the body of literature pertaining to the study of research. Views have been provided based on the literature survey done on the various works on using NSN and Nano Clay in concrete, strength test and durability test.

Chapter 3 Materials and Testing Methods

It explains the properties of the materials used and the procedure followed to conduct the various experiments to determine the physical, mechanical and durability properties of concrete.

Chapter 4 Results and Discussion

The results obtained from the various experiments are presented and inference made based on the results are discussed in detail using graphs, tables, pictures etc. in this chapter.

Chapter 5 Conclusions and Scope for future work

This chapter presents the analysis of results and the scope for future work.

6.0. CONCLUSIONS AND FUTURE SCOPE OF WORK

The effect of NSN and Nano Clay on fresh and hardened concrete and durability of concrete are presented here:

- The consistency test showed that there was increase in water demand with addition of NSN to cement.
- The superplasticizer requirement increased with an increase in NSN content.
- The 28-day compressive strengths were higher for concrete with NSN.
- The 28-day flexural strengths were higher for concrete with NSN.
- The 28-day split tensile strengths were higher for concrete with NSN.
- When the addition of SF and Nano Clay (1%), there was increase in the strength compared to concrete with only NSN.
- UPV test showed an increase in UPV speed with the increase in NSN content. The increase in UPV speed indicates the reduction in pores and an increase in density of concrete due to addition of NSN.
- The SEM image of sample with NSN and Nano Clay shows the concrete to have denser, compact and better gel formation with fewer pores.
- Sorptivity test showed a reduction in rate of surface water absorption with an increase in the NSN and Nano Clay quantity in concrete.
- RCPT shows that chloride ion penetration was controlled by the addition of NSN and Nano Clay.
- The low permeability of NSN and Nano Clay added concrete enhances the durability capability of concrete.
- The experiments proved that the addition of NSN and Nano Clay has positive impact on concrete’s strength and durability.

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